incident on the top *sloping* faces produces, after basal reflection, the lower oblique arcs; in the latter case, the general formulæ give

$$\cos d = \cos h \cos i',$$

where i', the second "angle of incidence" of the projected ray, is easily found from the Laws of Refraction.[6] Hastings fails to bring out in his paper the fact that

[6] Humphreys, W. J.: *Physics of the Air*, pp. 483, 488.

both the top sloping faces are required to produce the complete arcs; furthermore, he ascribes their inner extension from the anthelion, when seen, to light entering the top horizontal face only, whereas in reality the sloping face away from the sun also contributes to this.

Figure 3, fully explained in the legend, shows the complete theoretical halo, calculated for $H = 65°$, corresponding to the observation of Professor Palmer; the *full* lines show the features *actually observed*, as indicated in a sketch accompanying his letter.

HAYFORD ON EFFECTS OF WIND AND OF BAROMETRIC PRESSURE ON THE GREAT LAKES.[1]

By Alfred J. Henry.

In the above-named publication, Doctor Hayford presents an account of his researches on the general problem of evaporation from the surface of the Great Lakes. The research, which was begun in 1911, has for its ultimate object a better formulation of the laws governing the amount of stream flow than the engineering profession is now able to set forth. The problem is a fascinating one when it is considered that each of the Great Lakes is used as an evaporating pan under the conditions that obtain in nature. That it is complex goes without saying.

Doctor Hayford makes a radical departure from practically all known precedents when he makes no new observations but is content to use existing observational material, viz, the hourly and daily observations of the surface level of Lake Erie and Lake Michigan-Huron, supplied by the U. S. Lake Survey for its five stations, Buffalo, Cleveland, Harbor Beach, Mackinaw, and Milwaukee. Data of wind direction and velocity and of barometric pressure were obtained from Weather Bureau stations along the lakes, or, in the case of the pressure gradients, scaled from the forecast charts at the Chicago office of the Weather Bureau.

The method followed in the investigation may be summarized as follows:

(1) After the development of a theory as to the relations of the various quantities involved, that theory was expressed in the form of a general equation. The equations were then set up for a least-square solution to test the theory. Each equation expressed an observed quantity, a change in elevation of the water surface, in terms of other known or observed quantities, in conformity with the theory which was on trial. The solution was then made by the least-square method of computation. Out of these solutions arose a set of computed values of the unknowns assumed to be constants, which were supposed to express the relations between the observed quantities and a set of residuals which are the discrepancies between the tentative theory and the observed facts.

(2) The outcome of the least-square solution was then studied in the light of all available internal and external evidence. As the theory expressed in the observation equations of such a solution approaches more closely to perfection, the computed probable errors are smaller, the residuals, as a rule, are smaller, and the distribution of the residuals as to sign and magnitude follow the laws of accidental errors more closely. These tests furnished the main portion of the internal evidence. The external evidence was derived mainly (a) from comparisons of the outcome of the solution with that from other solutions already made, (b) from a study of apparently abnormal residuals, and (c) from general checks on the reliability

of the various items of outcome of the solution which were derived from any available information which was independent of the least-square solutions.

(3) In later portions of the investigation, the observed fluctuations of the elevation of the surface of the water were plotted in graphs, and the constants derived from the least-square solutions were plotted, superposed over the same scale. The graphs were then studied to secure further checks, contradictions, or suggestions.

(4) In the light of all evidence a new series of observation equations was then set up and the whole process of making a least-square solution and then studying the outcome repeated. In general, each new set of observation equations involved one or more of the following: (a) a change in the tentative theory, expressed as a change in the form of the observation equation; (b) a change in the data used, brought about by rejecting certain observation equations, or by combining certain others (two or more in a group) to form one; (c) the addition of a considerable amount of data, so as to increase the number of observation equations to at least double what it had been; or (d) the new observation equations were based upon an entirely independent group of data, elevations of water surfaces from a different gage, which might even be on a different lake.

The least-square method of solution was adopted as the principal means of attack on the problem because it was apparent that several different factors or influences were operating simultaneously to cause fluctuations of the elevation of the water surface at a gage, no one of which could be safely neglected while attempting to evaluate others.

The outcome of the investigations is stated in the following numbered paragraphs:

(1) Reasonably accurate numerical expressions have been obtained for the effects of barometric pressures on the elevation of the water surface at the five stations, Buffalo, Cleveland, Milwaukee, Mackinaw, and Harbor Beach, on Lake Erie and on Lake Michigan-Huron. With these expressions, one may, from the distribution of barometric pressures ordinarily shown on the forecast maps of the Weather Bureau, compute the disturbances in elevation of the water surface thereby produced at the stations named.

(2) The general method has been developed by which such a numerical expression for the barometric effect at any station on any body of water may be derived from observations of the water elevation at that station and the forecast maps for the same period.

(3) A general expression, including the necessary numerical constant, has been obtained for the effect of the winds, of any given velocity and direction, in producing a disturbance of elevation of the water surface at any given station, on any body of water, anywhere in the world. The data required in regard to the station and the body of water are such as are ordinarily shown on good charts, namely, the depths of the water at all points, the location of the shore line, and the location of the station.

[1] Hayford, John F.: *Carnegie Institution of Washington*, Publication No. 317.

(4) Four of the prevailing seiches, or free oscillations under the influence of inertia, on Lake Erie and Lake Michigan-Huron have been isolated. Their periods and probable methods of oscillation have been shown. The relation between these seiches and the uncertainties in daily mean elevations of the water surface at gage stations has been discerned. The appreciation of this relation aids decidedly in obtaining accurate determinations of the daily mean elevation of the mean surface of each lake.

(5) The accuracy with which the elevation of the mean surface of any one of the Great Lakes may be determined for any given day has been decidedly increased. On Lake Erie the elevation of the mean surface of the lake may now be determined as accurately from 1 day of observation at Buffalo as it was formerly possible to fix it from 16 days of observation at that station. Similarly, the elevation of the mean surface of Lake Michigan-Huron may now be determined as accurately from 1 day of observation at Mackinaw as it was formerly possible to determine it from 6 days of observation at that station. When one determines the fluctuation of elevation of the mean surface of a lake he thereby determines the fluctuation in the total water content of the lake.

(6) The relations of the new knowledge indicated in (1) to (5) to four outstanding problems have become evident. The four problems are:

(a) The problem of regulating the elevations of the water surface of each of the Great Lakes—and the rates of flow through the connecting streams, so as to secure the greatest aggregate benefits to navigation, power, development, and sanitation.

(b) The problem of determining the laws of evaporation from large free-water surfaces such as the surface of the Great Lakes.

(c) The problem of correcting the observed elevations of the water surface at a tide gage in such a manner as to remove the disturbances due to winds and fluctuating barometric pressures and thereby to secure a more accurate determination of mean sea level than could otherwise be obtained from said observations.

(d) The problem of determining the direction and rate of the tilting, which is believed to be in progress, of the land underlying and immediately surrounding the Great Lakes.

As to the accuracy of the results, the author considers it possible to determine the mean elevation of the whole of Lake Michigan-Huron, for example on any day, with a probable error of less than ± 0.010 foot, and that by using the three stations Milwaukee, Mackinaw, and Harbor Beach it would appear that the change in elevation of the mean surface of the whole lake for any one day may possibly be determined with a probable error of less than ± 0.007 foot—an accuracy hitherto unattainable.

NOTES, ABSTRACTS, AND REVIEWS.

Anton D. Udden (1886-1922).

On September 5, 1922, occurred the death of Dr. Anton D. Udden, at San Antonio, Tex. To those who were privileged to be associated with Doctor Udden, even for a short time, the news of his untimely death will be accepted with deepest regret.

It was not until 1917 that Doctor Udden's interest in meteorology was brought to the attention of the Weather Bureau, although he had taught meteorology, among other sciences, at Augustana College, Rock Island, Ill., for a number of years, and had completed most of the work required for the degree of Doctor of Philosophy in the University of Chicago. On January 1, 1918, he entered the service of the Weather Bureau as an observer at Davenport, Iowa; plans for undertaking research work at the Central Office in Washington were annulled by the induction of Doctor Udden into the military service on April 14, 1918, after only three and one-half months at the Davenport station. He was among the first of those selected by the Signal Corps to receive instruction in meteorology at College Station, Tex. Upon completing work in this school, Doctor Udden was assigned to Washington, D. C., and to the meteorological station at Cape May, N. J. Upon the completion of his military service, he resigned from the Weather Bureau to continue his work as instructor in physics at the University of Pennsylvania in Philadelphia. He was appointed McFadden Fellow of the American-Scandinavian Foundation and spent his last two years in study at the University of Copenhagen with Professor Bohr. His strenuous academic activities abroad culminated in a nervous collapse just as he was about to return to the United States. After receiving treatment during the summer in Christiania, he was brought by his wife and father to Texas late in August. His death from heart failure occurred only 11 days after arriving in the United States.

Doctor Udden's quiet demeanor, his modesty, his great capacity for work and study which revealed itself rather by his accomplishments than by brilliant display of knowledge, his genial disposition which remained placid under military circumstances ordinarily capable of irritating one of his attainments, his willingness to undertake commonplace tasks,—all are qualities which impressed his superiors and stimulated his fellows.

The publication of an article prepared by Doctor Udden is contemplated for an early number of the MONTHLY WEATHER REVIEW.—C. L. M.

Stefan C. Hepites (1851-1922).

Notice has been received of the death of the first director of the Central Meteorological Institute of Roumania, Stefan C. Hepites, at Braila, September 15, 1922, at the age of 71 years. Doctor Hepites was the organizer of the Roumanian Institute and devoted his life to researches in meteorology and other branches of geophysics.

The notice, signed by the present director, E. Otetelisnau, states that, during the reorganization period following the World War, the great experience and competence of the former director was of the utmost value to the Roumanian service.—C. L. M.

METEOROLOGICAL STATIONS IN THE ARCTIC.

Supervising Forecaster E. H. Bowie, writing in the Philadelphia *Public Ledger* of November 15, 1922, concerning the establishment of a chain of meteorological stations in the Arctic says:

Stations are already in operation in Spitzbergen, Iceland, Jan Mayer (east of Greenland), and Alaska, from which regions daily reports are received by radio. The Amundsen Arctic exploration steamship *Maud*[1] is another link in the chain of outposts in the far north.

Steps already have been taken to establish additional radio equipments and weather observatories in Greenland and Baffin Land; later, it seems probable, outposts will be operated in north central Canada and the north shore of Alaska; and eventually the chain of outposts will encircle the North Pole, along the Arctic Circle.

THE SUN'S ACTIVITY, 1890-1920.

[Reprinted from *Nature* (London), September 30, 1922, pp. 465-466.]

The sun, as is well known, is a variable star having a period of approximately 11 years, but, unlike other stars, its variability can be determined from several different visible phenomena and not solely from the total integrated

[1] Cf. this REVIEW, February, 1922, 50:74.